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# Attention, Arousal, and Memory in Posttraumatic Stress Disorder

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*Vietnam combat veterans with current posttraumatic stress disorder (PTSD), with other Axis-I disorders, or with no Axis-I disorders completed a series of tasks designed to elucidate the psychophysiological parameters of information-processing in PTSD. These tasks included a modified Stroop procedure (MSP), a standard Stroop procedure, a recognition memory task, and a threat rating task. Physiological responses were recorded throughout the study. Our data supported several predictions derived from information-processing models of PTSD. PTSD subjects exhibited greater MSP interference to high threat words than both comparison groups, and a liberal response bias toward recognizing military-related words. PTSD symptoms and threat reactions contributed to MSP interference effects for high-threat words after controlling for medications, depression, and baseline physiological activity.*

**KEY WORDS:** PTSD; Stroop; memory; arousal.

Conceptual models of posttraumatic stress disorder (PTSD) have been influenced by theories of human information-processing (e.g., Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988; Foa, Steketee, & Rothbaum, 1989; Horowitz, 1986). Although cognitive models of PTSD employ many different information-processing constructs to explain the etiology and maintenance of PTSD, the elements of a general model can be extracted and used as a heuristic to guide research. For example, Litz and Keane (1989) proposed the following as essential postulates of such a

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model: (a) trauma-related experiences are stored in memory in a hierarchically organized network or schema, which is (b) easily triggered by trauma-related cues, resulting in greater accessibility of trauma memories and integrated programs of conditioned emotional responses (e.g., physiological reactivity), leading to (c) preferential allocation of attention to potentially threatening stimuli in the environment. In effect, the trauma-network is distinguished from other organized self-relevant knowledge by virtue of its hyperaccessibility (i.e., ease of activation) and the type of responses that are produced subsequent to activation (e.g., hypervigilance, conditioned emotional responses, etc.).

In order to operationally define and measure the key cognitive and emotional responses in PTSD, researchers have borrowed methods and paradigms from experimental-cognitive psychology (e.g., Foa, Feske, Murdock, Kozak, & McCarthy, 1991; McNally, Kaspi, Riemann, & Zeitlin, 1990; Trandel & McNally, 1987; Zeitlin & McNally, 1991). To date, the problem most often studied in the laboratory has been biased or selective attention, and the paradigm most often applied in this context has been the modified Stroop procedure (MSP; see MacLeod, 1991). In the MSP, various word types are presented in different colors and subjects are told to name the color of presented words as quickly as possible, while ignoring their content. PTSD subjects are predicted to take longer to name the color of trauma-related words indicating the ease of activation of the network of trauma memories (McNally, English, & Lipke, 1993). Reaction times are increased because trauma-related stimuli are pre-potent for PTSD subjects and unwittingly draw on attentional resources leading to greater interference in the primary, color-naming response. Utilizing variants of the MSP, three separate experiments demonstrated increased color-naming latencies to trauma-related information in PTSD (Cassiday, McNally, & Zeitlin, 1992; Foa et al., 1991; McNally et al., 1990).

In the first study, McNally et al. (1990) exposed Vietnam combat veterans with and without PTSD to four different types of words (combat-related, obsessive–compulsive-related, positive, and neutral) printed on poster boards. PTSD subjects showed longer reaction times to all word types, but exhibited longer color-naming latencies to the combat words relative to all control words. However, this study had several limitations. First, because in the card variant of the MSP all the words in a given category are presented simultaneously, stimulus presentation time and subject behavior are uncontrolled (e.g., McNally, English, and Lipke, 1993). Thus, total reaction time to a given card may be influenced by factors such as random reading. Second, McNally et al. (1990) used obsessive–compulsive-related (OC) control words to determine if there are general threat-related, rather than trauma-specific, information-processing biases in PTSD. In our view, such

OC-related words (e.g., germs, urine) may not sufficiently test the generality of the trauma-network in PTSD because they are too distinct from the experience of veterans with PTSD.

In two subsequent studies investigating information-processing biases in rape-related PTSD, Foa et al. (1991) and Cassiday et al. (1992) utilized a computer-generated, single trial MSP, which improves experimental control over word presentation and subject response. Foa et al. presented rape words, general threat words, neutral words, and nonwords, finding an interference effect for rape-related stimuli in subjects with PTSD. Cassiday et al. (1992) also presented four word types in their study: High and moderately threatening rape-related words, as well as positive and neutral words. Similar to the findings of McNally et al. (1990), rape victims with PTSD exhibited longer reaction time latencies to all presented words, as well as to high and moderately threatening trauma-related words.

In the present study we investigated several issues left unaddressed in these previous studies. First, we sought to replicate and extend the findings of McNally et al. (1990) by exploring information-processing in combat-related PTSD, utilizing a computer-generated MSP. Also, we used high and low threat, military and education words as stimuli. The choice of these four categories allowed us to examine the separate effects of threat and content, permitting a test of the hypothesis that the MSP interference effect in combat-related PTSD is trauma-specific, as has been found in rape-related PTSD, rather than generally related to threat.

Second, we explored the association between MSP interference effects and peripheral autonomic arousal in PTSD by assessing heart-rate and skin-conductance responses at baseline and in response to the words used during the MSP. Chemtob et al. (1988) suggested that greater general or background arousal in PTSD primes the trauma network, thereby increasing the likelihood of selective attention to threat cues, while, Litz and Keane (1989) have argued that phasic reactivity plays a more important proximal role. In the present study, we used psychophysiological reactivity to high threat military words as an index of their threat-valence and predicted that this would correlate with MSP interference effects.

Third, we explored recognition memory for trauma-related words presented in the MSP. Although intrusive memories are an important aspect of the clinical syndrome of PTSD, only two studies have explored memory effects (McNally, Litz, Prassas, Shin, & Weathers, 1994; Zeitlin & McNally, 1991). In the study that is most relevant to the present investigation, Zeitlin and McNally demonstrated that PTSD subjects exhibit a memory bias for trauma-related information using a cued-recall procedure. Recall tasks are particularly sensitive to differences in the organization of memories and as such are quite appropriate to study in the context of PTSD. However, as

Litz and Keane (1989) point out, recall tasks do not allow for a formal examination of the influence of response bias or decision-making strategy, which they claim is important to examine in PTSD. In the present study, we used a recognition memory task and related signal detection analysis, allowing us to test three competing hypotheses about memory performance in PTSD.

If trauma-related stimuli are preferentially processed, leading to greater interference during the MSP, then as Zeitlin and McNally's (1991) findings suggest, this should lead to enhanced memory (discrimination) of such cues during a recognition memory test. However, current conceptual models of anxiety disorders suggest that anxious patients preferentially attend to threatening stimuli at initial stages of information-processing, but subsequently fail to elaborately encode such stimuli due to an avoidance of the negative emotional responses elicited by such cues. Although this pattern of vigilance and subsequent avoidance of cues is consistent with clinical descriptions of PTSD, it has not been empirically tested. If this hypothesis is valid, PTSD subjects should manifest a retrieval deficit for threatening stimuli previously presented during the MSP (i.e., reduced accuracy of recognizing such stimuli; see Mogg, Mathews, & Weinman, 1989). An alternative hypothesis proposed by Litz and Keane (1989), is that rather than showing deficits or enhancements in memory, per se, PTSD patients, by virtue of having extensive experience with threatening stimuli and attendant responses, manifest a liberal decision-making criterion for determining the presence of high threat stimuli. This criterion should be reflected in a liberal response bias (or Beta) for trauma-related words.

Fourth, both the Cassiday et al. (1992) and the McNally et al. (1990) studies showed that PTSD subjects take longer to name the color of all word types during the MSP. The underlying processes responsible for this general slowing during the MSP are unclear. It could be, for example, that PTSD patients have a general problem in maintaining attentional focus on a primary task such as color-naming, independent of the semantic nature of the stimuli. However, since only meaningful, semantic stimuli have been employed in MSP studies, this hypothesis remains untested. In the present study, we included a standard Stroop procedure (SSP) that requires subjects to name the colors of competing color names in order to empirically examine this issue.

Fifth, MSP effects in PTSD could be explained by a variety of third variables, including: extent of depression, the presence of medications that effect reaction time (RT), and resting levels of physiological arousal. To date, these third variables have only been examined with zero-order correlations between MSP RT's and continuous measures of depression and anxiety (e.g., McNally et al., 1990). In the present study we simultaneously explored several theoretically relevant multivariate predictors of MSP RT in order to examine the unique contribution of each to the variability in MSP RT.

Finally, no study exploring the information-processing characteristics of PTSD has employed a psychiatric control group, leaving unaddressed the question of specificity of biased cognitive processing of trauma-related stimuli. In the present study we included a group of Vietnam combat veterans with Axis I disorders other than PTSD as a psychiatric comparison group.

## Method

### *Overview*

Subjects completed a series of information-processing tasks, including a MSP, a SSP, a recognition memory task, and a threat-rating task. Physiological data were collected throughout the study. However, preliminary data analysis revealed no between word-type reactivity during the MSP, due to the brevity of exposure and the overriding influence of vocal response on physiological reactivity, thus these data were not used in subsequent analyses. Physiological responses during the recognition memory task were not analyzed because there were no predictions about these responses.

### *Design*

The design was a 3 (Group: PTSD, Well adjusted, and Psychiatric controls) × 2 (Threat-level: High vs. Low) × 2 (Content: Military vs. Education) mixed factorial, with threat-level and content as within subjects factors. For the MSP, a Latin Square design was used to counterbalance order of word type presentation (detailed below).

### *Subjects*

Subjects were veterans who served in the Vietnam theater of operations (war-zone) between 1964 and 1975. They were recruited from a variety of sources within the greater Boston area, including inpatient and outpatient treatment facilities. Three groups of subjects were formed: PTSD, well-adjusted controls (WELL), and psychiatric controls (PSYCH). Subjects were included in the PTSD group if they met the criteria for current PTSD on the basis of the PTSD module of the Structured Clinical

Interview for DSM-III-R (SCID; Spitzer, Williams, Gibbon, & First, 1990) and obtained a score of 107 or greater on the Mississippi Scale for Combat-Related PTSD (Mississippi Scale; Keane, Caddell, & Taylor, 1988). This composite diagnostic procedure is stringent and has been shown to increase diagnostic accuracy (Kulka et al., 1990).

Subjects were included in the WELL group if they did not meet the criteria for any current Axis I disorder on the SCID and scored below 107 on the Mississippi Scale. Subjects were included in the PSYCH group if they met the criteria for a current Axis I disorder other than PTSD on the SCID and scored below the cutoff on the Mississippi Scale. Potential subjects were excluded from the study if they were left-handed (due to the potential for laterality confounds), or if they had a psychotic disorder, or organic brain syndrome, and if they could not contract to not use any non-prescription drugs and/or alcohol for 24 hr before their participation in the study. All potential subjects were screened in advance for color blindness by asking them to name the four colors that were used in the MSP (see below).

There were 24 subjects in the PTSD group, 15 in the WELL group, and 12 in the PSYCH group. As shown in Table 1, the three groups were equivalent on key demographic characteristics, but not on military service characteristics (e.g., subjects' report of average type of duty). Table 2 presents the scores on the psychometric instruments administered to subjects, including the vocabulary subtest of the Wechsler Adult Intelligence Scale—Revised (WAIS-R). The PTSD group had higher Combat Exposure Scale (Keane et al., 1989) scores than the other two groups. However, all groups had, on the average, at least moderate exposure to the war-zone in Vietnam (Keane et al., 1989). The SCID data revealed the following additional current psychiatric diagnoses of note: (a) 42% of the PTSD group, relative to 8% of the PSYCH group, reported current major depression, (b) 8% of the PTSD group, relative to 58% of the PSYCH group, reported current alcohol dependence, (c) no PTSD subjects had a current diagnosis of drug dependence, while 58% of the PSYCH group reported drug dependence.

### *Stimulus Materials*

The stimuli for the MSP and recognition memory tasks consisted of a total of 96 words, with 24 words in each of four categories: high-threat military-related words (HM), low-threat military-related words (LM), high-threat education-related words (HE), and low-threat education-related words (LE). We randomly selected eight words from each category for the

Table 1. Demographic Information[a]

| Demographic Variable | Subject Group PTSD ($n$ = 24) | WELL ($n$ = 15) | PSYCH ($n$ = 12) |
|---|---|---|---|
| Age (mean) | 42.40 (2.31) | 43.20 (3.17) | 42.33 (2.19) |
| Education (mean) | 13.00 (2.93) | 14.47 (3.18) | 11.82 (2.89) |
| Race | | | |
| Black | 8% | 13% | 0% |
| Hispanic | 4% | 0% | 0% |
| Caucasian | 88% | 87% | 100% |
| Marital status | | | |
| Married | 45% | 71% | 17% |
| Single | 14% | 0% | 8% |
| Divorced | 14% | 21% | 50% |
| Separated | 18% | 7% | 25% |
| Live-In | 9% | 0% | 0% |
| Branch of service | | | |
| Army | 29% | 73% | 45% |
| Navy | 8% | 0% | 27% |
| Air Force | 0% | 0% | 9% |
| Marines | 63% | 27% | 18% |
| Type of duty[b] | | | |
| Mainly Combat | 67% | 27% | 35% |
| Combat Support | 18% | 71% | 60% |
| Service Support | 4% | 7% | 18% |

[a]Standard deviations are shown in parentheses.
[b]Subjects could report more than one type of duty, and some data are missing for this variable.

MSP, saving the remaining 16 words as distractor items for the recognition task.

In order to generate words for each of these categories, we conducted a preliminary word validation study. A heterogeneous group of 12 Vietnam theater veterans rated 200 education-related and 150 military-related words. Subjects rated each word for the extent to which it was representative of "military experience in Vietnam" and "schooling experience," using a 5-point Likert-type scale, ranging from "not at all" (1) to "very much" (5). Subjects also rated how threatened they were by each word on a 5-point scale ranging from "extremely nonthreatening" (1) to "extremely threatening" (5). Each dimension was presented on a different rating form, and words were randomly ordered on each of these forms, with the restriction that education words were always presented before military words.

**Table 2.** Mean Psychometric Scores[a]

| Variable | PTSD ($n$ = 24) | WELL ($n$ = 15) | PSYCH ($n$ = 12) |
|---|---|---|---|
| | Subject Group | | |
| MMPI PTSD Scale | 30.50[a] (8.46) | 12.27[b] (8.44) | 17.58[b] (8.02) |
| Mississippi Scale | 130.46[a] (15.55) | 81.08[b] (17.97) | 89.58[b] (16.00) |
| Combat Exposure Scale | 28.04[a] (8.50) | 15.42[b] (7.28) | 17.08[b] (9.32) |
| Beck Depression Inventory | 28.04[a] (9.62) | 10.73[b] (7.22) | 17.00[c] (7.42) |
| WAIS-Vocabulary | 42.46 (11.60) | 49.47 (8.61) | 43.83 (12.57) |

[a]Standard deviations are shown in parentheses. Nonshared superscripts are significant at the .01 level.

High-threat military words were operationally defined as those words with high threat ratings (i.e., greater than the mean) that were rated as most applicable to the military (i.e., greater than the mean) and least applicable to education (i.e., lower than the mean; e.g., ambush). The low threat military stimuli were the words that had low threat ratings that were highly applicable to the military and least applicable to education (e.g., jeep). The high and low threat education-related stimuli were chosen in a similar manner (e.g., detention, pencil). The word selection process was iterative so that categories of words could be formed that were matched on word length and frequency of usage, as per Kucera and Francis (1967) while differing on threat value and content (words available on request).

### *Apparatus*

All experimental events, with the exception of the physiological assessment, were controlled with an AST research Premium 286 personal computer. A 14-in. color monitor was used to present all stimuli in the study. Micro Experimental Laboratory software was used to control the presentation of the stimuli and collect all the information-processing data (Schneider, 1988; version 1.0). A Gerbrands model G1341T voice activated relay was used during both the SSP and MSP tasks. A standard microphone

(Tandy) unobtrusively positioned 6 in. from the subject's face was used to receive the voice response. All ratings for the recognition memory and threat rating tasks were made on the PC keyboard.

Physiological responses were measured with a Grass Model 7 polygraph located in an adjacent room. Heart-rate (HR) was recorded from plate electrodes placed in the standard lead 3 arrangement and connected to a Grass 7P3 amplifier. The raw EKG signal was converted to a beats-per-minute expression using a Grass 7P44B cardiotachometer. Beckman standard silver/silver chloride electrodes (16 mm diameter) were filled with specially prepared Unibase creme and attached by adhesive collars to the thenar and hypothenar sites of the left palm to measure skin conductance (according to Fowles et al., 1981). Responses were directly recorded by the polygraph using a Grass 7P1 preamplifier and a Slepner Skin Conductance Coupler (Slepner Electronics Corporation, Cherry Hill, NJ) that produced a constant output of 0.5 volts.

*Procedure*

After signing a consent form, subjects were administered a SCID by a specially trained doctoral-level psychologist, then completed the Mississippi Scale as well as the PTSD scale of the Minnesota Multiphasic Personality Inventory (MMPI-PTSD; Keane, Malloy, & Fairbank, 1984), the Beck Depression Inventory (BDI: Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961), and the Combat Exposure Scale (Keane et al., 1989). If eligible, a subject was invited back for participation in the experimental protocol, typically 1 or 2 days later. Immediately prior to the laboratory session, the subject was given the WAIS-R vocabulary test by a trained research assistant. The WAIS-R was used to ensure that the groups were equivalent in verbal intelligence. Subsequent to this, electrodes were placed on subjects and they were asked to relax during a 10-min baseline period. The MSP followed the baseline phase.

After receiving a series of instructions about the MSP, subjects were shown four colored rectangles depicting the colors used in the MSP (blue, green, red, and purple) on the monitor in the same size as the words presented in the MSP, with the actual color names below each rectangle. Subjects then were given a set of ten MSP practice trials consisting of number names ("one" through "ten") presented in different colors. All words were presented in 40 point type (approximately .8 cm), centered on the video screen.

In the MSP, subjects were told to name the color of a word as quickly as possible while ignoring the word's content. Each MSP trial consisted of a 3.5-sec inter-trial interval (blank screen), followed by a presentation of a fixation cross for .5 sec, followed by the presentation of a word stimulus .5 sec later. Each word was presented for a total of 2.5 sec (which represented a ceiling RT).

The SSP task followed the MSP after a one minute inter-task interval. The SSP consisted of 10 individually presented antagonistic color-words, presented with the same timing parameters as the MSP.

One minute after the Stroop tasks, subjects completed a recognition test. The 32 stimulus words from the MSP (targets) and the 64 unpresented distractor words (16 words from each of the 4 word types) were presented in a blocked randomized fashion. There were 32 blocks of three randomized words (one target and two distractors). Subjects made two judgments regarding their recognition memory for each trial. First, they judged whether an item was "old" (i.e., previously presented during the color naming task) or "new" (i.e., not previously presented). Two keys on the PC keyboard marked "OLD" and "NEW" were used for this response. Each word presentation was on the screen until an "OLD" vs. "NEW" response was given. Immediately after the recognition memory decision was made, a new screen appeared asking subjects to rate how confident they were in their "old / new" decision, using a 0 to 6 Likert-type scale ranging from "not at all" to "extremely." Specially marked numerical keys on the keyboard were used for this response. Subsequent to the confidence rating, there was an intertrial interval of 2 sec.

Finally, 1 min after the recognition memory task, subjects were asked to rate the degree to which all 96 stimulus words were threatening to them. Words were presented in blocks, by category, in the following order: HM, LE, HE, LM. Threat judgments were made on a 0 to 6 Likert-type scale ranging from "not at all" to "extremely." Numerical keys on the keyboard were also used for this response.

## Data Reduction and Analysis

### *Modified Stroop Procedure*

For the MSP, a Latin Square design was used to balance the order of presentation of word categories (Winer, Brown, & Michels, 1991). Each set of four subjects within a group were randomized to the rows of a 4 × 4 Latin Square. The rows of the Latin Square were the order in which the categories were presented to each subject. The four categories of words were generated by two factors: Threat-level (high vs. low) and content (military vs. education). For the PTSD group, there were six Latin Squares and for the other groups there were three.

Words were presented in blocks of 16 per category in a fixed order; each word in each category was presented twice to each subject (i.e., the 8 target words were followed by the same 8 words in a block). Group, order of presentation, and word category were treated as fixed factors. Individual subjects and words were regarded as random factors. Because the distribution of scores for the raw color naming RT latencies was found to be nonnormal, these data were normalized using a natural log transformation.

Qualitative information about each MSP trial was recorded by hand by a research assistant. Trials with word-naming errors, incorrect color-naming errors, and noncolor-naming responses (e.g., coughs) were not included in the statistical analyses. A repeated measures ANOVA was used to analyze the MSP data, followed by a series of interaction contrasts to examine between group differences (Keppel, 1991).

### *Physiological Assessment*

A skin conductance response (SCR) was operationally defined as an increase in skin conductance of at least 0.1 microsiemens within a 5-sec interval. The total number of SCR's in a given epoch was calculated. Skin-conductance level (SCL) was also calculated throughout the experiment but was only analyzed during the baseline period because SCL did not produce a reliable index of reactivity to the various information-processing tasks. The cardiotachometer provided a continuous measure of inter-beat interval and yielded a beat-by-beat estimate of HR over time. The highest HR value in a given epoch was calculated. The physiological data were analyzed within a repeated measures ANOVA framework. Since any number of medications can influence physiological activity, all subjects were asked to list the medications they were currently taking. Medications were categorized as either autonomically deactivating (e.g., Benzodiazepines, Beta-blockers, etc.), or not.

*Baseline*. The last minute of the 10-min baseline period was used as the measurement interval to evaluate resting physiological activity. It was assumed that the last minute would best capture the resting activity for subjects after 9 min of quiet rest. The highest HR was identified for consecutive 10-sec intervals, and a mean of these six values was used as the resting HR value for a 1-minute period. For SCR, the total number of SCR's within the 60-sec period was calculated. For SCL, the lowest value in each 10-sec period was calculated during the last minute of the baseline and a mean was derived based on these six values. The decision rule for SCL allowed for the creation of an index of skin conductance that is disaggregated from the number of SCR's.

*Standard Stroop Procedure*. The 10 trials of the SSP lasted for approximately 1 min. The number of SCR's that reached criterion within that time period were analyzed. The highest heart rate value for each 10-sec epoch was also recorded, and a mean HR was calculated. Baseline physiological values were subtracted from SSP values in the data analysis in order to index physiological reactivity during the SSP.

*Threat rating task*. Each category of words took approximately 2 min to rate. Physiological data were calculated in the same manner for this task as for the SSP.

### Recognition Memory

Specific hypotheses concerning recognition memory and response bias were tested using a nonparametric signal detection analysis procedure (McNichol, 1972). Confidence ratings were combined with "old" versus "new" responses to create a 14-point scale (1 = "new" rating at a confidence of 7, 2 = "new" rating at a confidence of 6, and so on). The derived scale ranged from very certain "new" (1) to very certain "old" (14) responses. For each subject, four memory operator characteristic curves (MOC; see McNicol, 1972) were constructed reflecting the mean hit rate (% correct identification of a word as "old") as a function of the false alarm rate (% incorrect identification of a word as "old") for each word-type. Each point along the confidence scale was used to identify 14 points along the MOC curve for each subject.

The probability of the area under the MOC curve P(A), was used as the nonparametric measure of memory sensitivity (see Hartwick, 1979). Values of P(A) can range from chance levels (.5) to perfect discrimination (1.0). P(A) has been shown to approximate d-prime, the standard parametric method used to assess memory discrimination when the "old" and "new" distributions are normal. Since the distribution of P(A) was highly negatively skewed, the data were square-root transformed.

The measure of memory bias was the nonparametric B, which is derived by identifying the confidence value where a given subject is equally disposed to "old" and "new" responses (McNicol, 1972). Response bias or B scores range from 0 to 14, where low scores indicate a lax criterion, and high scores indicate a strict criterion. Both P(A) and B data were analyzed with a 3 (Group) × 2 (Content) × 2 (Threat-level) repeated measures ANOVA.

## Results

### *Stroop Reaction Time*

*Modified Stroop Procedure.* Table 3 shows the means and standard deviations for the untransformed RT latencies (in milliseconds) during the MSP for each group and each word type. Mean response latencies were submitted to a repeated measures ANOVA. There was a main effect for group ($F(2,44) = 4.77$, $p = .013$). As in the McNally et al. (1991) and Cassiday et al. (1992) studies, follow-up contrasts of group revealed that the PTSD group exhibited longer RT latencies when compared with both the WELL and PSYCH groups ($F(1,44) = 5.93$, $p = .019$ and $F(1,44) = 6.90$, $p = .012$, respectively). The main effect of threat was not significant ($F(1,28) = 1.3$, $p = .26$), although there was a marginal main effect for content, that is, all subjects took longer to color-name military words ($F(1,28) = 3.8$, $p = .06$). The main effect for Group was modified by a significant Group by Threat interaction ($F(2,56) = 6.51$, $p < .003$), with no Group by Content interaction effect ($F(2,56) = 2.32$, $p = .11$). The Group by Content by Threat interaction effect was also nonsignificant ($F(2,56) = 1.20$, $p = .30$).

Follow-up, interaction contrasts comparing PTSD subjects with both the WELL and PSYCH groups on MSP interference effects for high versus low threat words (collapsed across content) were significant ($F(1,56) = 7.82$, $p = .007$, and $F(1,56) = 9.70$, $p = .003$, respectively). PTSD subjects took longer to name the color of high threat words than the two control groups.

*Standard Stroop Procedure.* The mean RT's (in milliseconds) for each group were as follows: PTSD = 1271.3 ($SD$ = 276.8), WELL = 1077.6 ($SD$ = 168.6), and PSYCH = 1195.4 ($SD$ = 202.6). A one-way (group) ANOVA revealed a difference in color-naming latencies during the SSP that approached significance ($F(2,48) = 2.73$, $p = .085$). However, post-hoc

**Table 3.** Color Naming Latencies during the MSP[a]

| | Subject Group | | |
|---|---|---|---|
| Variable | PTSD ($n$ = 24) | WELL ($n$ = 15) | PSYCH ($n$ = 12) |
| High-threat military | 1151.57 (378.67) | 943.28 (187.00) | 890.17 (209.29) |
| Low-threat military | 1081.60 (333.62) | 904.27 (184.41) | 851.77 (157.94) |
| High-threat education | 1082.07 (333.77) | 875.51 (171.30) | 845.36 (162.42) |
| Low-threat education | 1029.29 (263.81) | 887.11 (169.76) | 862.67 (107.81) |

[a]Standard deviations are shown in parentheses.

contrasts (Tukey) revealed no significant (<.05) group differences. Due to the exploratory nature of employing a SSP with Vietnam combat veterans, and in order to avoid Type-II error, we also conducted between group t-tests on SSP RT. These more liberal analyses revealed a significant difference between the PTSD and the Well group only ($t(1,34) = 2.22, p = .03$).

## Physiological Data

### *Baseline*

Baseline physiological data are shown in Table 4. Separate one-way ANOVA's revealed no group differences either for HR ($F(2,48) = .12, p = .89$), SCL ($F(2,44) = .84, p = .44$), or the number of SCR's ($F(2,48) = .51, p = .60$).

### *Standard Stroop Procedure*

Separate one-way ANOVA's were used to analyze each measure of reactivity to the SSP by group. There were no group differences found on number of SCR's ($F(2,48) = 1.94, p = .15$). As can be seen from the raw data depicted in Table 4, all groups showed substantial phasic reactivity, as indexed by skin conductance, during the SSP. There was a significant group effect for HR ($F(2,48) = 5.46, p = .007$). Post hoc (Tukey) comparisons revealed that the PTSD group had lower HR change scores than the WELL group ($p < .05$). These data reveal that PTSD subjects are no more physi-

**Table 4.** Physiological Responsivity during Baseline and during the SSP[a]

| | Subject Group | | |
|---|---|---|---|
| Variable | PTSD ($n$ = 24) | Well ($n$ = 15) | Psych ($n$ = 12) |
| Baseline | | | |
| SCL | 3.40 (3.02 | 2.41 (1.84) | 4.17 (2.41) |
| SCR | 1.17 (1.17) | .60 (1.40) | .83 (1.40) |
| HR | 84.42 (12.20) | 82.57 (7.52) | 83.25 (15.16) |
| Standard Stroop Procedure | | | |
| SCR | 6.38 (6.22) | 5.33 (5.07) | 9.17 (3.97) |
| HR | 81.96 (11.17) | 84.44 (7.78) | 81.08 (15.63) |

[a]Standard deviations are shown in parentheses. Baseline HR values may be artificially elevated due to the scoring rule applied to these data.

ologically reactive to the SSP, which has been used in analogue studies to produce stress reactions (e.g., Tulen, Moleman, Van-Steenis, & Boomsma, 1989), a finding that is consistent with previous research that has demonstrated content-specific physiological reactivity in PTSD (Blanchard, Kolb, Gerardi, Ryan, & Pallmeyer, 1986).

### *Threat Rating Task*

The analysis of physiological responding concurrent with the threat-rating task revealed no between group effects, but considerable within-subject differences for number of skin conductance responses only. Both the PTSD and the WELL groups had a greater number of skin conductance responses to high threat, relative to low-threat words (high threat: $M = 7.3$, $SD = 7.5$, for the PTSD group; $M = 4.6$, $SD = 5.1$, for the Well group, and low threat: $M = 4.5$, $SD = 6.1$, for the PTSD group; $M = 3.3$, $SD = 4.2$, for the Well group; $F = 14.36$ (1,31), $p = .001$; $F = 8.98$ (1,31), $p = .01$, respectively).

## Recognition Memory

### *Recognition Memory Sensitivity*

Recognition memory sensitivity, or P(A), is shown as a function of word type in Table 7. The repeated measures ANOVA showed a main effect of content ($F(1,48) = 28.43$, $p = .0001$) and threat ($F(1,48) = 7.60$, $p = .008$). There were no significant interaction contrasts. As can be seen by the P(A) values shown in Table 5, all subjects, regardless of word-type, demonstrated extremely accurate recognition memory.

### *Response Bias*

Recognition memory response bias, or B, is also shown as a function of word type in Table 5. The repeated measures ANOVA showed a main effect of content ($F(1,48) = 43.15$, $p = .0001$) and threat ($F(1,48) = 5.55$, $p = .02$), as well as a content by threat interaction ($F(2,48) = 6.47$, $p = .01$) and a group by content interaction ($F(2,48) = 4.51$, $p = .02$). PTSD subjects demonstrated a lower decision making criterion for Military versus Education words, in comparison to the WELL group only ($F(1,44) = 5.66$, $p = .05$).

**Table 5.** Recognition Memory Data[a]

| Word-Type | PTSD (*n* = 24) | WELL (*n* = 15) | PSYCH (*n* = 12) |
|---|---|---|---|
| | | P(A) | |
| High-threat military | .924 (.07) | .947 (.03) | .930 (.06) |
| Low-threat military | .908 (.07) | .908 (.07) | .907 (.07) |
| High-threat education | .859 (.08) | .916 (.07) | .883 (.09) |
| Low-threat education | .872 (.08) | .900 (.05) | .852 (.08) |
| | | B | |
| High-threat military | 4.52 (4.41) | 7.67 (4.74) | 5.46 (4.19) |
| Low-threat military | 4.84 (4.52) | 6.50 (4.46) | 6.21 (4.60) |
| High-threat education | 9.73 (4.13) | 7.60 (4.47) | 7.90 (4.93) |
| Low-threat education | 11.24 (3.13) | 10.24 (2.49) | 11.12 (2.90) |

[a]Standard deviations are shown in parentheses.

**Table 6.** Threat Ratings[a]

| Word-Type | PTSD (*n* = 24) | WELL (*n* = 15) | PSYCH (*n* = 12) |
|---|---|---|---|
| High-threat military | 4.97 (1.22) | 4.36 (1.20) | 4.28 (1.13) |
| Low-threat militarty | 2.44 (1.44) | 2.11 (1.11) | 2.06 (.99) |
| High-threat education | 2.33 (1.28) | 2.70 (1.24) | 2.67 (1.40) |
| Low-threat education | 1.40 (.40) | 1.29 (.32) | 1.26 (.28) |

[a]Standard deviations are shown in parentheses.

## Threat Ratings

Threat-rating data are presented in Table 6. Threat-ratings were submitted to a 3 (Group) × 2 (Content) × 2 (Threat) repeated measures ANOVA. Main effects of content ($F(1,47) = 104.71, p < .001$) and threat ($F(1,47) = 238.35, p < .001$) were qualified by a content by threat interaction ($F(1,47) = 21.51, p < .001$). These data show that high threat military words were rated as more threatening than the high threat education words. There were no statistically significant between group interaction contrasts.

Table 7. Correlations Between MSP Reaction Time Variables and Other Measures

| | Mean Reaction Time | | | Mean High Threat Reaction Time | | |
|---|---|---|---|---|---|---|
| | *r* | *N* | *p* | *r* | *N* | *p* |
| MMPI-PTSD | .36 | 46 | .007 | .34 | 46 | .01 |
| Mississippi Scale | .30 | 48 | .02 | .28 | 48 | .03 |
| Combat Exposure Scale | .23 | 48 | .06 | .27 | 48 | .03 |
| Beck Depression Inventory | .31 | 44 | .02 | .30 | 44 | .02 |
| Threat ratings for high-threat words | .33 | 48 | .01 | .29 | 48 | .02 |
| Baseline SCL[a] | .05 | 44 | .35 | .08 | 44 | .26 |
| Standard Stroop SCR's[a] | .04 | 45 | .41 | .04 | 45 | .40 |
| Number of SCR's for high-threat words during threat-rating task[a] | .24 | 39 | .06 | .24 | 39 | .06 |
| Sympathetic deactivating medications[b] | .30 | 48 | .01 | .28 | 48 | .03 |

[a]Partial correlations, using current use of sympathetically active medications (yes/no) as the covariate, were used with skin conductance data (SCL and SCR).
[b]The correlation between use of sympathetically deactivating medications and baseline HR = −.38, $p$ = .004, and baseline SCL = −.20, $p$ =.08.

## Multivariate Predictors of MSP Interference Effects

Table 7 presents zero-order correlations between overall mean MSP RT's and MSP RT's for high threat words (collapsed across content) with measures of psychopathology, threat-ratings, and physiological arousal. These two MSP variables were chosen because they represent the two significant findings of the present study. Both MSP RT variables were significantly positively correlated with: PTSD measures, the threat-valence of the words used in the study (measured via self-report and physiologically), BDI scores and the use of sympathetic deactivating medications.

We also employed a hierarchical multiple regression equation to predict mean MSP RT for high threat words (see Table 8). The goal was to determine the extent to which PTSD symptomatology, and the threat-valence of the high threat words used in the study, contribute to the MSP interference effect, after controlling for the third variables that showed significant zero-order relationships with MSP RT. The independent variables employed in each equation were: use of sympathetic deactivating medications (presence or absence), BDI scores, SCL at baseline (indexing resting arousal), a composite index of the threat-valence of MSP words, and a composite PTSD index. A more reliable index of the ideographic threat value of the high threat words was created by computing a composite score reflecting the mean of the *z*-scores of subjects' threat ratings for the high

**Table 8.** Predictors of Mean High Threat MSP Interference Using Hierarchical Multiple Linear Regression

| Predictor | Mean High-Threat MSP Reaction Time | | |
|---|---|---|---|
| | Beta | Partial $r$ | $p$ |
| Sympathetic deactivating medictions | .21 | .22 | .18 |
| Beck Depression Inventory | −.14 | −.08 | .63 |
| Baseline SCL | −.01 | −.01 | .95 |
| Threat Valence Index[a] | .29 | .31 | .05 |
| PTSD Index[b] | .36 | .38 | .01 |

[a]A composite score was computed providing an index of the threat value of the words used during the MSP. The composite was computed as the mean of the $z$-scores of subjects' threat ratings for the high threat words that were presented during the MSP and the $z$-scores for the number of SCR's that were elicited during the threat rating task for those high threat words.

[b]A composite score, combining each PTSD index (Mississippi Scale and MMPI-PTSD scale), was created in order to provide a more reliable continuous index of PTSD. The composite was computed as the mean of the $z$-scores for the two tests.

*Note.* The $R^2$ for this equation = .21 ($F(2,36) = 4.89, p = .01$).

threat words that were presented during the MSP and the $z$-scores for the number of SCR's that were elicited during the threat rating task for those same high threat words. Also, in order to provide a more reliable index of PTSD symptomatology, we computed the mean of the $z$-scores for the two PTSD tests (Mississippi Scale and the MMPI-PTSD scale) and used this variable in the regression equation to index PTSD.

The only significant independent variables in the equation were the PTSD index and the threat-valence index. The partial correlations between the threat-valence index and the PTSD index, and high-threat MSP RT's were .31 and .38, respectively. The complete model accounted for 23% of the variance in mean MSP RT to high-threat stimuli. Contrary to the prediction of Chemtob et al. (1988), there were no independent effects of resting physiological activity on information-processing biases indexed by the MSP. These data reveal the unique contribution of PTSD symptom reporting and threat reactions to MSP interference.

## Discussion

Subjects with PTSD in our study demonstrated a generalized threat-related attentional bias displaying a decrement in color-naming for all high threat stimuli. This effect was highly specific to PTSD status in that PTSD subjects showed this high-threat MSP interference effect, in comparison with both the well-adjusted and psychiatric control groups. These data stand in contrast with several studies that demonstrated PTSD to be associated with increased color-naming for trauma-related threat stimuli specifically. However, they are consistent with the theoretical view that a distinguishing feature of the trauma-network in chronic PTSD is its elaborately interconnected and highly generalized character. This is hypothesized to be due to the intensity and personal significance of original and subsequent conditioning and learning experiences surrounding the events (Foa et al., 1989; Litz, 1992; McCann & Pearlman, 1989).

It contrast to our findings, Foa et al. (1991) found only a specific MSP interference effect in rape victims with PTSD within a year of their assault, but Cassiday et al. (1992) found that rape victims with PTSD, who were tested an average of nine years after their trauma, had greater RT's both to highly threatening rape words and to moderately threatening words, suggesting a more generalized effect. Perhaps in chronic PTSD (manifested in the types of outpatients sampled in our study), the trauma-network has become more generalized over time, encompassing a variety of threat-related stimuli. An alternative explanation is that Vietnam combat veterans with PTSD may have had the kinds of painful failure experiences in school, prior to (or after) service that lead to preferential processing of these types of stimuli, independent of war-zone-related trauma.

Another performance characteristic of PTSD confirmed in this study was significantly increased color naming latencies, regardless of content, in the MSP. Although all groups exhibited longer mean RT's during the SSP than during the MSP, there were no reliable group differences. The longer RT's during the SSP for subjects is not surprising given the inherent difficulty in naming the color of competing color names, versus naming the color of words of various sorts in the MSP (MacLeod, 1991). These two findings taken together suggest that any stimulus having some degree of personal relevance, regardless of threat-valence, has the capacity to interfere with ongoing task demands (e.g., color naming) in PTSD. It is important to appreciate, however, that the interaction effect of threat makes the main effect of RT difficult to interpret. It could be that there is a general slowing of color-naming RT's for PTSD subjects during the MSP because of the general threat effect during the MSP.

Our data showed that severity of PTSD and the threat valence of the to-be-processed stimuli explain the most variance in selective attention to threat in combat veterans. Although PTSD caseness is most likely to lead to information-processing biases in those reporting the requisite number and type of symptoms, our correlational data suggest that anyone who has been exposed to potentially traumatizing events (e.g., a war zone), and who develop some degree of PTSD symptoms, are at risk for unwittingly having their attention drawn to personally salient, highly threatening stimuli in the environment, to some degree.

Our memory findings are partially consistent with the Litz and Keane (1989) hypothesis that PTSD is associated with a response bias toward trauma-related stimuli during memory retrieval, rather than a retrieval deficit. The vigilance–avoidance hypothesis was not supported in our data, neither did we replicate the findings of Zeitlin and McNally (1991). Rather, our data suggest that veterans who have been exposed to war-zone stress and have significant clinical distress share a tendency to liberally identify military-related information in the environment. This response bias appears to be particularly salient in PTSD. Although it is difficult to generalize from the analogue recognition memory task to actual behavior in the environment, it could be that combat veterans who are distressed have a highly reinforced learning history of early and liberal recognition of military-related cues. The response cost for errors in recognition memory decisions (false positives) is quite low, but the psychological consequences of false negative decisions (failing to recognize a threat cue in the environment) would be very high. Although the use of a liberal detection rule for military-related information is dysfunctional because it is likely to lead to false-alarm reactions (see Jones & Barlow, 1990), it is nevertheless reinforced because it facilitates optimal avoidance of potentially threatening cues (Litz & Keane, 1989).

Finally, several methodological limitations of the present study should be noted. First, since the groups were not equivalent on combat exposure scores, it could be that the differences in information-processing characteristics could be attributed to severity of combat exposure as much as severity of PTSD. In order to rule out the role of the severity of exposure to Criterion A events as an explanatory variable, future studies should employ groups who have been exposed to the identical degree and type of potentially traumatizing events, but who differ on PTSD status alone. Second, as mentioned above, by using education words as control stimuli, we may have unwittingly increased the likelihood of finding an interaction of group and threat in the MSP. Third, since subjects in the PTSD were allowed to freely vary in terms of co-morbid psychiatric conditions, we can not be absolutely certain that our results are not in part attributable to general distress or other specific psychiatric syndromes, such as major depression. However, there are several features to our findings that mitigate concerns about the issue of co-morbidity. The construct of general distress is ruled out as an alternative explanation for information-processing biases related to PTSD in that the PTSD subjects were found to respond to high threat stimuli differently than the psychiatric control group. Also, when examined in a multivariate framework, depression (the most prevalent comorbid condition observed in the PTSD group), failed to account for significant variance in the MSP effects seen in the study. Finally, although we employed twice as many distractor words than targets in our recognition memory task, it still may have been too easy to recognize targets, leading to a ceiling effect for discriminability. Future studies should use either a complex and demanding interpolated task and/or a long inter-task interval in order to allow for greater variability in recognition performance. A longer inter-task interval, for example, would more likely lead to either elaboration/rumination or avoidance/suppression of the to-be-remembered stimuli, thereby providing a better test of the vigilance–avoidance hypothesis.

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